

# Exposures to Toluene Diisocyanate (TDI) in Polyurethane Foam Plants

ALEXANDER B. RAKOW, D.O., and EDWARD J. BAIER, M.P.H.

**P**OLYURETHANE foam began to gain a strong foothold in the industrial market of the United States about 15 years ago. Since then, this material has been used increasingly for insulation of buildings, trucks, and refrigerators, for noise attenuation, and for cups for hot drinks. The main ingredient in the manufacture of such foam is toluene diisocyanate (TDI).

In 1957, Zapp (1) discussed the hazards that the isocyanates pose in the production of polyurethane foam. Various authors since have explored the respiratory effects of exposure to isocyanates (2), have clinically appraised workers exposed to these compounds (3), have suggested methods for medical control of the persons exposed, and have pointed out the toxicological considerations in handling these substances (4,5).

## Review of Earlier Environmental Studies

To define the extent of the adverse health effects of TDI in Pennsylvania, the environmental studies conducted by the division of occupational health of the Pennsylvania Department of Envi-

ronmental Resources during a 12-month period in 1966 and 1967 were reviewed. The exposures of workmen in 17 plants had been evaluated in these environmental studies. These plants produced refrigeration units, electrical insulation, drinking cups, urethane articles such as picnic baskets, foams, and hat bands, and also paints, coatings, and resins. In some of the plants, TDI was used to coat rubber rolls, labels, and rings, to coat hooks on safety slings, and to coat quartz crystals.

Fifty-five air samples were collected. The average exposure at the workman's breathing level was 0.004 p.p.m., and ranged from no TDI detected to 0.072 p.p.m. The "ceiling value" for TDI, that is, the maximum concentration permitted in the breathing zone at any time, is 0.02 p.p.m., because of the potential of this compound to sensitize workmen. Once a workman is sensitized, any exposure to TDI, regardless of how minute, causes severe asthma-like attacks. The highest exposures were from actual foaming operations, with coating operations running a close second, as the following table shows:

Kind of operation	TDI concentration (p.p.m.)
Foaming (mixing and pouring) . . . .	None detected-0.072
At reactor vessel . . . . .	0.004- .032
Emptying molds . . . . .	None detected- .011
Transferring foam . . . . .	0.003- .016
Curing area . . . . .	None detected- .033
Cut-off saw . . . . .	" " - .008
Coating . . . . .	0.002- .032

---

*Dr. Rakow is an industrial hygiene physician in the division of occupational health, Pennsylvania Department of Environmental Resources, and Mr. Baier is director of the division. Tearsheet requests to Division of Occupational Health, Pennsylvania Department of Environmental Resources, P.O. Box 2351, Harrisburg, Pa. 17120.*

Twenty-six studies had been made in the 17 plants, nine before 1966. The concentrations found in seven of the studies done before 1966 exceeded the ceiling value, exposures being as high as 0.072 p.p.m.

### Residual Effects of TDI Sensitization

To determine whether there were any residual effects of TDI sensitization, 12 employees who had reportedly been sensitized were located and questioned about any current symptoms they could report. Inquiry was also made into their previous occupations, specific occupation at the time of onset of the TDI reaction, and their occupations since the reported reaction.

The medical history of each of the 12 men was reviewed, including body systems, any known allergies, and any upper respiratory infections (see Form for Medical Review). Information on chest X-rays was sought, but this source failed to indicate any specific lung condition.

The questioning of the employees about their present medical status was directed toward such symptoms as breathing difficulties, wheezing, coughing, chest pain or tightness, head or throat complaints, or any sensitivities. Smoking habits were also determined.

Only one of the 12 members of the group continued to work at the same plant and in the same department as 8 years ago, when he had reported his sensitivity. The other 11 had found their way to different industries or positions. None of the 12 now work in an environment similar to the one in which they became sensitized.

All 12 of the sensitized employees had worked in the foam-making area, either at the foaming machine or along the conveyor transporting the newly made foam. They had worked at the plants for periods ranging from 2 weeks to 6 months before the episodes of sensitivity occurred. Their attacks were characterized by severe breathing difficulties coupled with tightness or pain in the chest. One man was hospitalized for 2 weeks. A return visit to the same work area by any of these men produced an immediate unfavorable response, such as wheezing and tightness in the chest.

The study of the men's medical histories revealed that three of them admitted to attacks of hay fever. The succeeding medical histories of the 12 men paralleled those found during the initial investigation. One man, who has since suffered a heart attack, had been a miner before he worked with foam. One man described a constant cold, and another claimed he has had hay fever since

## FORM FOR MEDICAL REVIEW

Name \_\_\_\_\_ Age \_\_\_\_\_ Telephone No. \_\_\_\_\_

Address \_\_\_\_\_

### A. Occupational history

1. Previous occupational history
2. Specific occupation at time of onset of symptoms
3. Succeeding occupational history

### B. Medical history

1. Systems review
2. Past medical history
3. Present medical symptoms
  - a. Frequent colds
  - b. Asthma
  - c. Cough
  - d. Chest pain or tightness
  - e. Sinus trouble
  - f. Sore throat
  - g. Sensitivities (allergic manifestations)
4. Social history (smoking)

his episode of sensitization. None expressed any desire to return to the site of their past exposure. Eight of the 12 regularly smoked cigarettes.

Admittedly, the study group was limited in size. It was chosen because the affected persons seemed to be available and were in an area where it appeared they would not be difficult to locate. Half of these men, however, had left the area by the time of our survey so that information could be secured only by phone. At the time of the incidents, a great deal of work was being done to correct working conditions at these plants. Exposure levels were then excessive, but current levels are less than 0.01 p.p.m. No cases of TDI sensitization have been reported in the past 2 years.

During the medical evaluations, we reviewed the residual effects of TDI on the 12 workers who became sensitized. Because all but one of the 12 sensitized men had by then moved to different geographic areas, they could not be readily examined. Nevertheless, of the symptoms described, a residual cough was apparently the most frequent symptom remaining. This symptom might, of course, be allied with some other factor, such as smoking. At the time of the medical evaluations, the frequency of various symptoms among the 12 men was as follows:

<i>Symptoms</i>	<i>Times reported</i>
Cough	4
Chest pain or tightness	3
Asthma	2
Allergic manifestations	2
Frequent colds	1
Sinus trouble	1

### Measures to Control TDI Exposure

At the time of the sensitization incidents, exposure levels of TDI were excessive, but current levels are less than 0.01 p.p.m., and no cases of TDI sensitization have been reported in the past 2 years.

To reduce the likelihood of such sensitization, management must be informed of the effects of TDI on the health of workers. In instances of significant exposure, proper techniques for handling materials are not enough; engineering control is needed. The following table shows the frequency with which various engineering control measures were recommended to reduce exposure to toluene diisocyanate in the 17 plants studied:

<i>Control recommended</i>	<i>Frequency of recommendation</i>
Local exhaust ventilation with adequate make-up air and maintenance	11
Closed system, covered system, or both	4
General dilution ventilation	3
Better instructions to workmen	3
Isolation of the operation	2
Curtains to reduce cross-draft	2
Neutralizing spills immediately	2
Removal of circulating fan	1

Whenever local exhaust ventilation, improved dilution ventilation, or closed handling systems were recommended, proper devices for respiratory protection were required as an interim measure.

Medical recommendations for further protecting the workmen from sensitization were made. To identify workmen showing the effects of overexposure to TDI, periodic chest X-rays and lung function tests are necessary. To protect the skin against contact with TDI, the use of gloves, skin creams, and proper outer garments is required.

In spite of control measures, however, cases of occupational disease have continued to occur. Such occurrences are possible even though exposures are apparently reduced to a minimum. The only explanation appears to be that workers become sensitized from spilled material or from exposure to TDI while it is chemically reacting. Our study, although on a small scale, points up the fact that prevention of exposures sufficient to sensitize workers is the paramount means of control for TDI. Education, engineering, and proper handling techniques are essential, but often these measures are effected only after a workman has been sensitized.

Interestingly, when the engineering control measures we have described were applied, cases of

### Reduction of TDI exposure in one plant during the foaming operation through proper engineering control

<i>April 2, 1965</i> <sup>1</sup>	<i>June 8, 1966</i>	<i>May 3, 1967</i>
0.013	0.056	None detected
.002	.020	Trace <sup>2</sup>
.007	.012	Trace
.072	.005	0.009
.015	.004	Trace
.014	....	Trace
.020	....	....

<sup>1</sup> Previous survey by an insurance company indicated concentrations to 0.11 p.p.m.

<sup>2</sup> About 0.0005 p.p.m.

TDI sensitization decreased remarkably. These measures, together with better screening procedures at the time of hiring and the removal from exposure—and at times, the dismissal—of a worker manifesting symptoms, have contributed to a reduction in cases.

It should also be noted that the 12 cases studied became manifest in a relatively short period after the men's exposure. Two weeks was the shortest time and 6 months the longest. The man whose symptoms took 6 months to appear was the only sensitized man still employed at the plant where he became sensitized. In reviewing the exposure level for this specific plant, which was included in the surveys conducted by the division of occupational health, we find that the workmen's exposures, before control was instituted at the foam-making operation, exceeded the ceiling value of 0.02 p.p.m. of TDI. The plant now maintains its own monitoring program, and results of this program indicate that the levels have remained in the range of 0.01 p.p.m. These levels have been substantiated by air samplings conducted by the division.

### Conclusion

We tried to uncover some new or different pattern of exposure and symptoms, but the results,

like those in all previous papers, point to the development of respiratory symptoms among workers exposed to TDI in amounts greater than 0.02 p.p.m. Once sensitized, the worker is usually not able to return to TDI exposure.

As significant, perhaps, as the medical results, is the realization that engineering control can reduce the exposure of the employee (see table). And upon reduction of exposure, cases of TDI sensitization decrease.

Of passing interest is the fact that treatment of the sensitized workers was for symptoms.

### REFERENCES

- (1) Zapp, J. A.: Hazards of isocyanates in polyurethane foam plastic production. *Arch Industr Health* 15: 324-330, April 1957.
- (2) Peters, J. M., Murphy, R. L. H., Pagnotto, L. D., and Van Ganse, W. F.: Acute respiratory effects in workers exposed to low levels of toluene diisocyanate (TDI). *Arch Environ Health* 16: 642-647, May 1968.
- (3) Bruckner, H. D., et al.: Clinical and immunologic appraisal of workers exposed to diisocyanates. *Arch Environ Health* 16: 619-625, May 1968.
- (4) Woolrich, P. F., and Rye, W. A.: Urethanes. *J Occup Med* 11: 184-190, April 1969.
- (5) Elkins, H. B., et al.: Massachusetts experience with toluene di-isocyanate. *Amer Industr Hyg Assoc J* 23: 265-272 (1962).

---

**RAKOW, ALEXANDER B.** (Pennsylvania Department of Environmental Resources), and **BAIER, EDWARD J.:** *Exposures to toluene diisocyanate (TDI) in polyurethane foam plants. Report on 12 TDI sensitized workmen. HSMHA Health Reports, Vol. 86, July 1971, pp. 663-666.*

A serial review of environmental studies was made in 17 plants in Pennsylvania to relate occupational exposure to TDI (toluene diisocyanate) to residual effects on workmen. Twelve employees were affected, who had worked in these plants for 2 weeks to 6 months before their

episodes of sensitivity. At the time of the study only one of the 12 was still working in the same department in which he had become sensitized.

A comparison of the TDI exposures in one plant before and after institution of proper

engineering control indicated that such control can significantly reduce employees' exposure. The medical status of the men was reviewed but revealed only that those exposed to TDI in amounts greater than 0.02 p.p.m. developed respiratory symptoms.